18 NUTRIENT INTERACTIONS

Success in the control of crop production will be achieved when scientists can reliably produce the yield that the genetic potential of the plant and the solar/radiation at the site make possible. This can be achieved by gaining a full understanding of a particular crop production system—its components, the interactions that impact yields, and the properties and processes of the basic working resources (soil and inputs).

Most soils are generally deficient to some degree in more than a single essential plant nutrient. Unless all deficient elements are supplied in adequate quantities, benefits from the application of even large amounts of a single nutrient are not realized. This limiting of the expression of the effects of one plant nutrient due to limited supply of another nutrient is due to their interaction. A careful study of these interaction effects on different soils and in different crops permits balanced fertilization, which is the key for the realization of production potential of a genotype in any crop. Furthermore, the extent and severity of nutrient deficiencies increase with an increase in the intensity of agriculture in a region, and so does the practical significance of nutrient interactions. This chapter explains the interaction effect and provides some examples of the nutrient interactions in crop production.

18.1. INTERACTIONS

When the effect of one factor is influenced by the effect of another factor, the two factors are said to interact. Furthermore, when the combined effect of two factors is more than their additive effects, the interaction is said to be positive (or synergistic). When their combined effect is less than their additive effects, the interaction is said to be negative (antagonistic).

For example, in a field experiment with mustard (*Brassica juncea* L.) grain yields shown in Table 18.1 were obtained. The response of mustard to N was greater when S was applied, and the response to S was greater when N was applied. The combined effect of N and S was greater than the sum of the individual effects of N and S. Yield with both N and S was increased 1.2 Mg ha^{-1}, compared with 0.99 (0.77 plus 0.22) Mg ha^{-1} when considered separately. Standard statistical procedures are available for determining the

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Table 18.1 Grain Yield of Mustard (Mg ha^{-1}) as Influenced by Nitrogen and Sulfur Fertilization

kg N ha^{-1}	kg S ha^{-1} 0	30	Response to S
0	0.45	0.67	0.22 (in the absence of N)
90	1.22	1.65	0.43 (in the presence of N)
Response to N	0.77 (in the absence of S)	0.98 (in the presence of N)	

From Dubey and Khan. 1993. Indian J. Agron. 38:270–276.

interaction effects and testing their significance. This is an example of a positive interaction. Recognizing the potential for positive interactions and capitalizing on them is the secret of successful crop production. Examples of negative interactions will be provided later in this chapter.

18.2. INTERACTIONS OF PRIMARY MACRONUTRIENTS

Interactions of primary nutrients have received considerable interest from the agronomists and soil scientists (Prasad et al., 1992; Dev, 1992). A number of researchers have reported data supporting positive N × P interaction. For example, data on N × P interaction in sorghum (*Sorghum bicolor*) at four locations in India having different soils are shown in Figure 18.1. In all four soils the response to N increased when P was applied; the increase was greatest on red soil. Thus in soils that are severely deficient in P, application of N alone will produce only a small increase in yield, much below the potential. Likewise, when N is provided as an ammonium or ammonium-producing fertilizer, the acidifying effect can enhance P solubility and thus provide a positive interaction. In some situations the contribution of N × P interaction can be large enough to overshadow the effects of N or P alone. As an example, the data from field experiments with sorghum and fingermillet (*Setaria italica* L.) grown under dryland agricultural conditions are shown in Table 18.2.

Tropical soils such as ultisols and oxisols are poor in soil P and K, and field experiments on such soils provide interesting data on N × K and P × K interactions. Data from Brazil (Figure 18.2) (PPI, 1988) show a positive N × K interaction in rice. A good response to K was obtained only when adequate N (90 kg ha^{-1}) was applied. Also, the response to N increased as the level of K was increased; the highest yield of rice was obtained when both N and K were applied at 90 kg ha^{-1}. Data on P × K interaction in pearl millet (*Pennisetum typhoides* L.) on similar soils are provided in Figure 18.3. Response to K was obtained when adequate P was applied. Again the highest dry matter was

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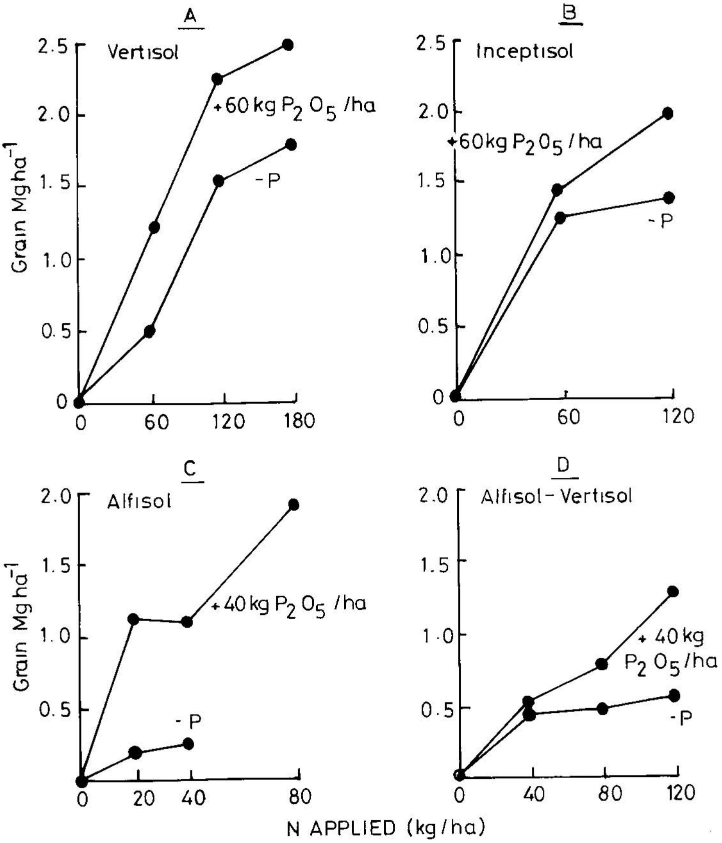

Figure 18.1. **N × P interaction in sorghum at four locations in India. A. Mishra and Singh, 1978; B. Roy and Wright, 1973; C. Venkateswarlu and Rao, 1978; D. Nagre and Bathkal, 1979. (From Sharma and Tandon, 1992. *Management of Nutrient Interactions*, pp. 1–20. With permission of Fertilizer Development and Consultation Organization, New Delhi, India.)**

Table 18.2 Response of Sorghum and Finger Millet to N and P Alone and in Combination (N + P)

	Response to			Estimated contribution of		
Crop	N (kg ha^{-1})	P (kg ha^{-1})	N + P (kg ha^{-1})	N (%)	P (%)	NP interaction (%)
Sorghum	110	490	1570	7	31	62
Finger millet	390	170	1300	30	13	57

From Tandon. 1992. *Fertilizer Management in Dryland Agriculture*, p. 59. With permission of Fertilizer Development and Consultation Organization, New Delhi, India.

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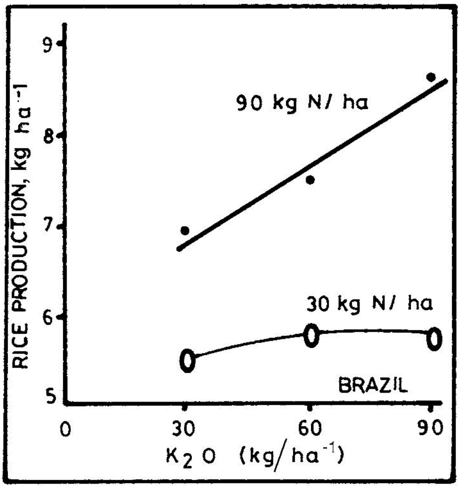

Figure 18.2. **Effects of N and K fertilization on rice. (From *Better Crops International*, December 1988, p. 9. With permission from Phosphate and Potash Institute.)**

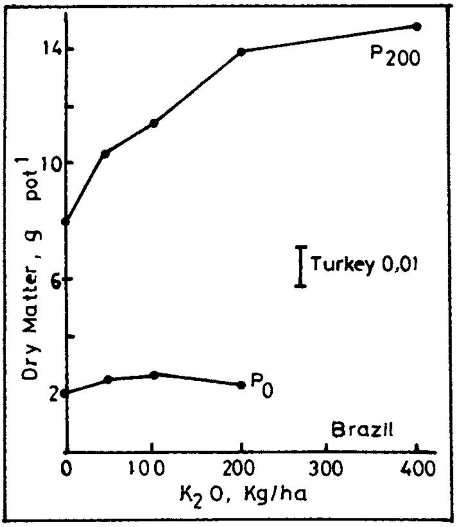

Figure 18.3. **Effects of P and K on pearl millet. (From *Better Crops International*, December 1988, p. 10. With permission from Phosphate and Potash Institute.)**

produced when both P and K were applied. Thompson et al. (1986) from North Dakota reported a positive response to P × K interaction in irrigated alfalfa (Table 18.3).

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Table 18.3 Alfalfa Forage Yield and Return as Influenced by P, K, and PK Application (Averaged over 1983, 1984, and 1985)

Treatment ($kg\ ha^{-1}$)		Forage	Return
P_2O_5	K_2O	($Mg\ ha^{-1}$)	($\$\ ha^{-1}$)
0	0	11.2	20.19
50	0	11.9	43.87
0	100	11.6	–1.50
50	100	12.7	132.37
100	250	13.3	95.75

From Thompson et al. (1986).

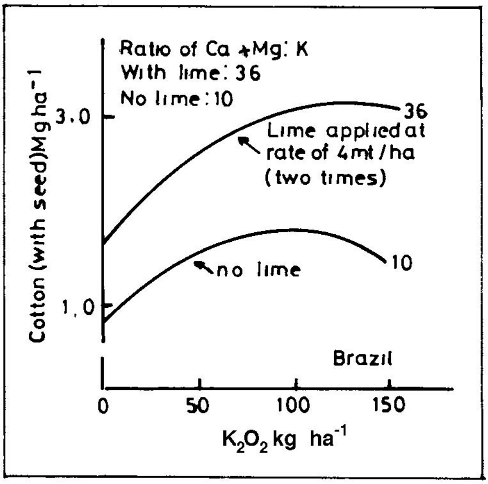

Figure 18.4. Effect of K on cotton 5 years after liming. (From *Better Crops International*, December 1988, p. 11. With permission from Phosphate and Potash Institute.)

Ca, Mg, and S may interact among themselves, but more interesting interactions are between them and NPK. N × S interaction has already been discussed (see Table 18.1). Darst et al. (1993) from Alabama reported a significant lime × P interaction in crimson clover (*Trifolium incarnatum* L.); response to lime was obtained only when adequate P was applied.

A liming and K fertilization experiment on a red latosol showed a positive interaction in cotton; the response to K was much greater when Ca + Mg:K ratio was 36 than when it was only 10 (Figure 18.4). In experiments where K application increases corn yield, generally a negative K × Ca and K × Mg interaction is observed in respect of Ca, Mg, and K concentration in leaves (Figure 18.5).

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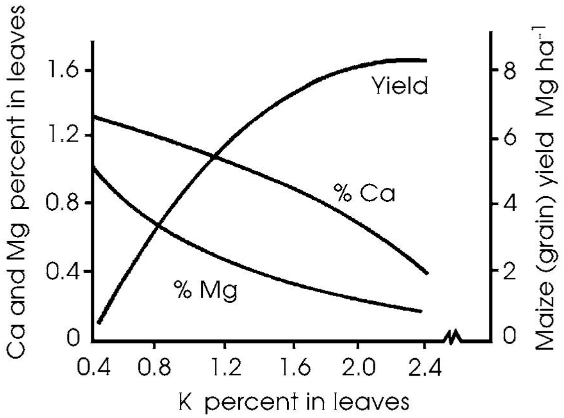

Figure 18.5. Potassium, Ca, and Mg content in corn leaves and effect on grain yield. (From *Better Crops International*, December 1988, p. 71. With permission from Phosphate and Potash Institute.)

18.3. INTERACTIONS OF MICRONUTRIENTS

Micronutrients may interact among themselves, or with secondary or primary nutrients. One of the most studied and reported interactions is P × Zn. Takkar et al. (1976) showed that increasing the level of P above 44 kg ha^{-1} significantly decreased roots, stems, leaves, shoots, and grain yield in corn — a negative interaction. This effect could be overcome only when adequate Zn was applied (Figure 18.6). Similar data for rice are shown in Figure 18.7 (Tiwari and Pathak, 1978). The reasons for phosphate-induced Zn deficiency include (1) P depressed soil-Zn availability; (2) P reduced Zn absorption by roots and subsequent retardation in Zn translocation from roots to shoots; (3) Zn dilution in plant tops arising from P induced growth response; (4) P-Zn imbalance–related metabolic disorder(s); and (5) P activated interference in Zn functioning (Olsen, 1972; Katyal et al., 1992).

Karle and Babula (1985) reported a highly positive B × S interaction in ground nut (*Arachis hypogea* L.) on a S- and B-deficient Vertisol at Parbhani, India. The contribution of B x S interaction was 22% in kernel yield and 43% in oil yield (Figure 18.8); the interaction was much more pronounced in oil yield. Sulfur increased oil yield by 73% and B by 29%, while the combined application of B and S increased oil yield by 181%.

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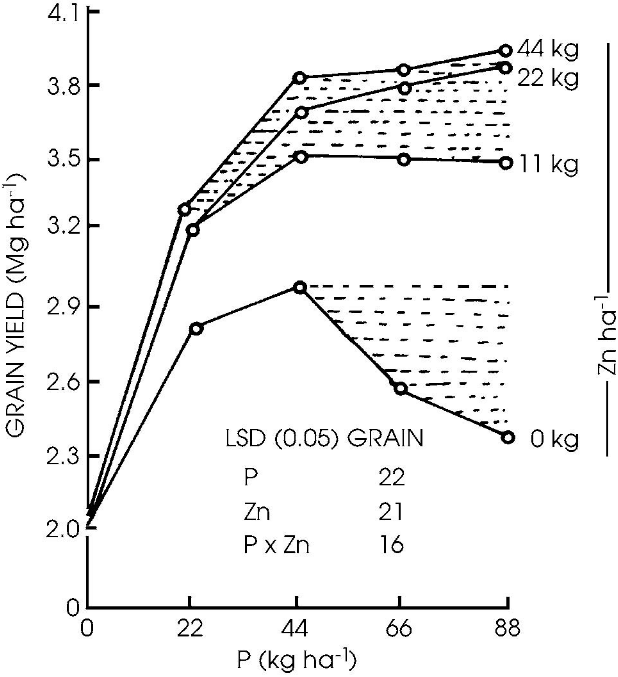

Figure 18.6. Corn grain yield (average of 3 years) as influenced by P and Zn interaction. The shaded area indicates P-induced Zn deficiency. (From Takkar et al. 1976. Agron. J. 68:942–946.)

Another example of the negative interaction is that of Cu and Mo. Application of high doses of Cu decreases Mo concentration in alfalfa, while increased Mo application results in decreased Cu concentration in rice. Because micronutrients are associated with enzymatic activities in plants, the reduced concentration of one micronutrient due to increased application of another micronutrient expresses itself in such activities. For example, excess Cu not only decreases Mo concentration in corn grown in refined sand at a low Mo level, but also inhibits its metabolic functioning by decreasing the protein-N concentrate and nitrate reductase activity and increasing peroxidase activity (Agarwal, 1989).

A negative interaction between B and Ca has been reported in wheat, pea, cotton, and alfalfa (Fox, 1968; Chauhan and Powar, 1978).

The above are only a few examples. The literature on agronomy, plant nutrition, and soil science contains numerous data on nutrient interactions. Research on intensive agriculture and farming systems will add more such examples to the literature.

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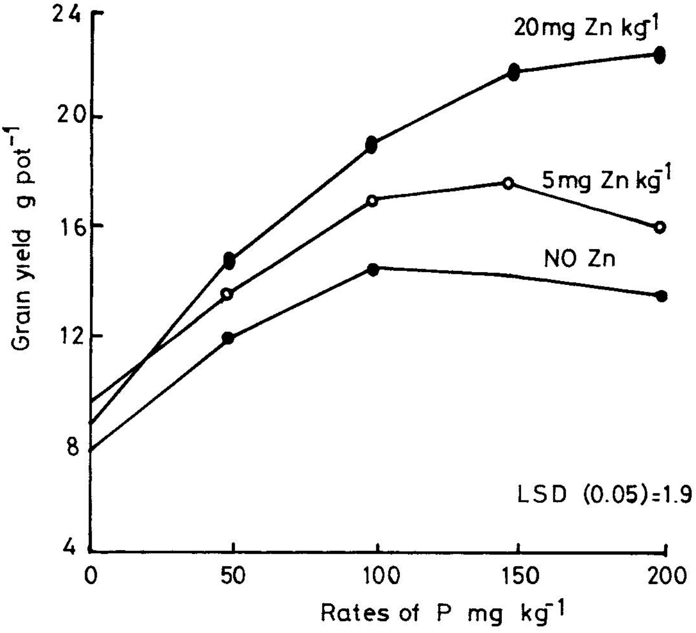

Figure 18.7. Interaction effect of Zn and P on rice grain yield. (From Tiwari and Pathak 1978. J. Indian Soc. Soil Sci. 26:385–389.)

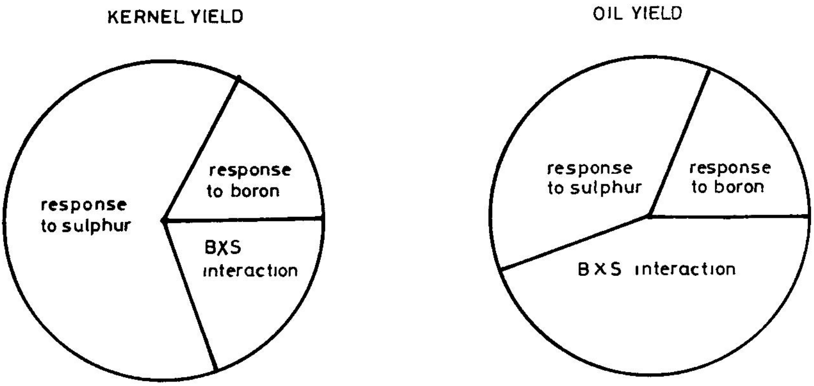

Figure 18.8. Partitioning of response of groundnut to S and B in groundnut. (From Karle and Babula, 1985; Tandon, 1992.)

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